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Delaying sheep grazing after wildfire in sagebrush steppe may not affect vegetation recovery

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Abstract. Although many land managers prohibit grazing for 2 years after a fire, little research has been conducted to determine the interaction of grazing with vegetation recovery after fire. In a study conducted in sagebrush steppe rangelands after a 2000 wildfire at the United States Sheep Experiment Station in Idaho, the influence of delay and season of sheep grazing on vegetation recovery was measured. A moderate level of sheep grazing was started 1, 2, or 3 years after fire in the autumn or 2 or 3 years after fire in the spring. *Pseudoroegneria spicata*, the dominant perennial grass, and *Crepis acuminata* increased in the autumn and non-grazed treatments, whereas perennial forb and *Crepis acuminata* cover declined in the spring grazing treatments beginning the second year after fire. There was no impact of sheep grazing on cover of *Bromus tectorum*, an important exotic winter annual grass, probably owing to the lack of autumn germination. In this study, moderate sheep grazing had subtle impacts on vegetation recovery after fire, with spring grazing having more negative consequences. Management decisions on when to start grazing livestock after fire should consider pre-fire ecological conditions, post-fire climatic conditions, and current knowledge of impacts of grazing on plant recovery.

Additional keywords: arid ecosystems, *Artemisia tripartita*, *Bromus tectorum*, *Crepis acuminata*, grazing management, grazing season, plant cover, *Pseudoroegneria spicata*, wildland fire.

Introduction

Wildfire in shrublands and grasslands creates many challenges for land and livestock managers around the globe. Livestock grazing is a dominant use of these rangelands and the decision to delay grazing after fire, if at all, might have important ecological and future management consequences. Land managers will often defer livestock grazing for several seasons after fire with the intent to promote plant vigor and ecosystem recovery. The concept of extended rest periods to compensate for the cumulative effect of both grazing and fire seems intuitive. However, extended rest periods may not facilitate ecosystem recovery and extended rest can impose unwarranted financial hardship on livestock producers. The challenge to land managers is to determine when and how to begin grazing after fire to maintain productivity of native perennial herbaceous species.

Fire is a natural and inevitable event in sagebrush-dominated ecosystems. Sagebrush steppe communities evolved with regular and widespread wildfires that historically occurred in 20 to 50 year cycles (Houston 1973; Arno and Gruell 1983; Lesica *et al*. 2007). There have been many studies in the sagebrush steppe in Idaho and Utah related to the impacts of fire on plant succession (Harniss and Murray 1973; Barney and Frischknecht 1974; Young and Evans 1978; West and Hassan 1985). Other studies have measured the response of different plant species such as *Festuca idahoensis* (Idaho fescue) and *Pseudoroegneria spicata* (bluebunch wheatgrass; Conrad and Poulton 1966; Patton *et al*. 1988), perennial bunch grasses in general (Wright and Kemmedson 1965; Uresk *et al*. 1980), and early succession vegetation community (Seefeldt *et al*. 2007) recovery after fire.

Domestic livestock grazing in the sagebrush steppe ecosystem has occurred for only the last 150 years, though the ecosystem evolved with significant herbivory by large generalist herbivores (Burkhardt 1996). In an early study, it was determined that ~40% of the perennial herbaceous biomass in the sagebrush steppe can be removed annually without causing degradation (Pechanec and Stewart 1949). In the Upper Snake River Plain of Idaho, there have been several important studies of the response of vegetation to sheep grazing, including the impact of seasonal grazing (Pechanec and Stewart 1949; Mueggler 1950; Laycock 1967; Bork *et al*. 1998; Seefeldt and McCoy 2003).

Little research has addressed how plant recovery after fire is influenced by herbivory (Jirik and Bunting 1994; Bunting *et al*. 1998; Seefeldt and McCoy 2003). Major ecological concerns after fire include potential weed invasion and erosion or soil loss (D'Antonio and Vitousek 1992). One argument against suspension of grazing after fire is that weedy species such as *Bromus tectorum* (cheatgrass or downy brome) may have greater opportunity for establishment (Knapp 1996; Mosley 1996).

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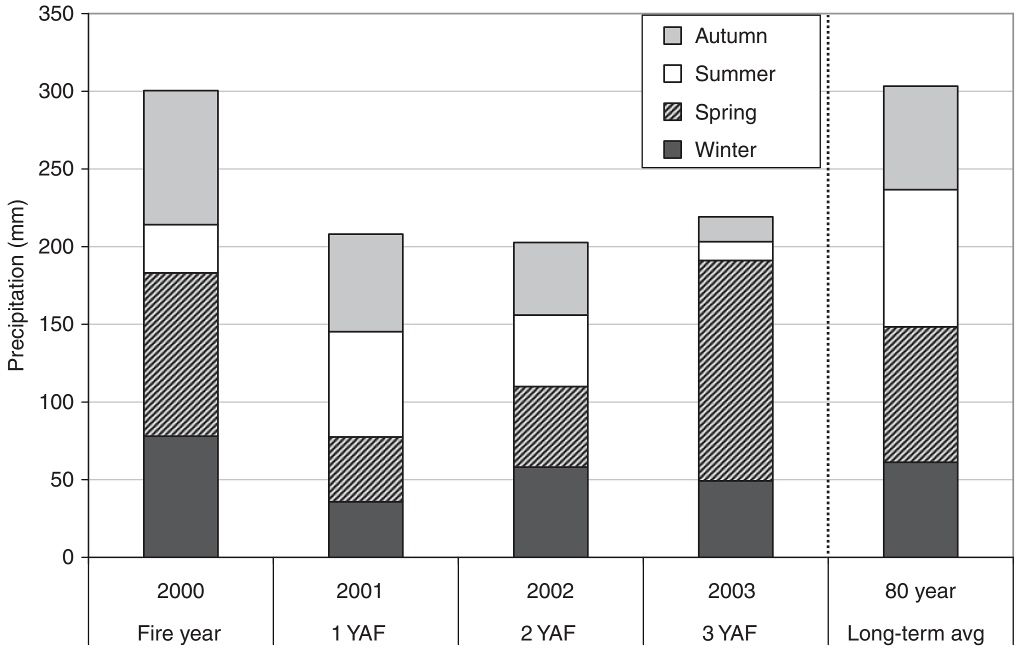

Fig. 1. Mean annual precipitation of a research site at US Sheep Experiment Station near Dubois, ID, in 2000 through 2003 (1, 2, and 3 years after fire (YAF)). The long-term average seasonal precipitation is also presented for winter (December–January–February), spring (March–April–May), summer (June–July–August), and autumn (September–October–November). Data obtained from Western Regional Climate Center, http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?iddubo, accessed 7 August 2006.

Loss of the sagebrush-steppe bioregion to *B. tectorum* invasion after fire is inarguably one of the greatest threats to western rangelands (Whisenant 1990; Knapp 1996). Early research documented that carefully applied sheep grazing may be an effective tool to manage *B. tectorum* (Daubenmire 1940; Pechanec and Stewart 1949; Hulbert 1955). Without grazing to suppress them, invasive or noxious weeds may take advantage of nutrient and water resources in the early spring when native species have not yet initiated growth. Thus, post-fire grazing management may inadvertently promote weed invasion.

Current policy pertaining to grazing management of public lands states that burned areas should be rested from grazing until documented monitoring results show that post-burn management objectives have been met (Bureau of Land Management 2007). However, the delay of grazing after fire may leave annual grass spread unchecked. Until 2007, the policy mandated a 2 year rest from grazing after fire on public land (Bureau of Land Management 1999) – a blanket policy which was not well supported by research and one that may have inadvertently promoted the spread of invasive species.

Methods

Study area

Research was conducted from 2001 to 2004 at the United States Department of Agriculture – Agricultural Research Service – US Sheep Experiment Station (USSES), ∼10 km north of Dubois, Idaho (44°14′N latitude and 112°12′W longitude). The study area is a sagebrush-steppe ecosystem dominated by *Artemisia tripartita*, *Pseudoroegneria spicata*, *Balsamorhiza sagittata*, and *Crepis acuminata*. Soils are fine-loamy, mixed, frigid Calcic Agrixerolls derived from wind-blown loess, residuum or alluvium, on slopes ranging from 0 to 12% (NRCS 1995). Climate of the study area is characterized by cold winters (average 6.1°C) and warm summers (average 18.5°C; Western Regional Climate Center 2006). Average annual precipitation for the research site is 303 mm, primarily from spring and summer rains (Western Regional Climate Center 2006).

Research site

A wet winter and spring followed by a hot and dry summer created optimal fire conditions in 2000 (Fig. 1). In the winter and spring before the wildfire, the research site received 127 and 121% of the long-term seasonal average precipitation respectively. Summer 2000 was dry, with the area receiving 35% of long-term average precipitation (Fig. 1). In July 2000, a 474-ha lightning-ignited wildfire burned a portion of the USSES, resulting in a patchwork of burned and unburned vegetation. Twenty-four research paddocks, ranging in size from 2.4 to 3.3 ha, were constructed in the burned area, creating a 69-ha research site. The soil and vegetation were generally uniform over the majority of the site with intermittent patches of rocky ground and little topographical variation. Unburned vegetation comprised 4 to 12% of the research paddocks. Paddocks were arranged in four blocks with six randomly applied grazing treatments in each block.

Table 1. Plant species examined in 2001 and 2004 in pre- and post-treatment measurements at research site in south-eastern Idaho

Paddocks were subjected to sheep grazing in spring or autumn 1, 2, or 3 years after a wildfire that occurred in 2000. Cover measurements were estimated in broad life-form categories and further subdivided by species. Scientific names follow the USDA Plants Database (https://plants.usda.gov, accessed 3 March 2008)

Life-form	Scientific name	Common name
Perennial grass	*Achnatherum hymenoides* (Roem. & Schult.) Barkworth	Indian ricegrass
	Agropyron cristatum (L.) Gaertn.	Crested wheatgrass
	Elymus lanceolatus (Scribn. & J.G. Sm.) Gould	Thickspike wheatgrass
	Hesperostipa comata (Trin. & Rupr.) Barkworth	Needle and thread grass
	Koeleria macrantha (Ledeb.) Schult.	Prairie junegrass
	Poa secunda J. Presl	Sandberg bluegrass
	Pseudoroegneria spicata (Pursh) A Löve	Bluebunch wheatgrass
Perennial forb	*Allium* L. spp.	Onion
	Astragalus L. spp.	Vetch
	Balsamorhiza sagittata (Pursh) Nutt.	Arrowleaf balsamroot
	Crepis acuminata Nutt.	Tapertip hawksbead
	Comandra umbellata (L.) Nutt.	Bastard's toadflax
	Taraxacum officinale F.H. Wigg.	Dandelion
	Tragopogon dubius Scop.	Yellow salsify
Annual grass	*Bromus tectorum* L.	Cheatgrass
Woody	*Artemesia tripartita* Rydb. spp. *tripartita*	Threetip sagebrush
	Chrysothamnus viscidiflorus (Hook.) Nutt.	Green rabbitbrush
	Gutierrezia sarothrae (Pursh) Britton & Rusby	Broom snakeweed
	Purshia tridentata (Pursh) DC.	Antelope bitterbrush
	Tetradymia canescens DC.	Gray horsebrush

Grazing treatments

Grazing treatments were applied to examine the effects of season of grazing (autumn *v.* spring) and the delayed onset of grazing after fire (1, 2, or 3 years after fire). The six grazing treatments included three autumn treatments (initiated in 2001, 2002, and 2003), two spring treatments (initiated in 2002 and 2003), and an ungrazed control. Grazing for autumn treatments occurred from late September to mid-October and spring grazing trials occurred from late May to early June. Once grazing treatments were initiated, they were applied in subsequent study years in designated seasons.

Sheep used for grazed treatments were dry ewes that were crosses of Columbia, Rambouillet, Targhee, and Polypay breeds. Sheep were provided by the USSES. Average sheep weight was 74 kg (67–77 kg $\pm$ 1.8 (s.e.)). Stocking rates varied substantially throughout the trial but averaged $\sim$120 sheep days ha^{-1} and were set to utilize 40% of available forage based on pregrazing biomass estimates. Typically, paddocks were stocked with 24 to 36 sheep for 7 to 14 days. The autumn 2001 grazing trial had a low stocking rate of 56 sheep days ha^{-1} owing to low biomass production in the year following the fire. All procedures related to animal use were approved by the University of Idaho Animal Care and Use Committee as protocol no. 2002–14.

Pre- and post-treatment vegetation measurements

Vegetation composition and site characteristics were first assessed the year after fire in the summer of 2001, before grazing treatments were applied. Vegetation assessment was repeated in 2004 following all treatment applications. Vegetation sampling consisted of cover and density estimates in 60 rectangular quadrats (30.5 $\times$ 61.0 cm) located along three pace-transects in each paddock. Transects were oriented west to east parallel to the north paddock border and evenly spaced across each paddock. Canopy cover of shrubs, perennial and annual grasses, perennial and annual forbs, and non-vegetated ground cover was estimated to the nearest 5%. These broad cover categories were further subdivided into estimates of individual dominant plant species that contributed to the broad categories (Table 1). Density of *Bromus tectorum* was recorded in each quadrat and *Artemisia tripartita* plants were counted in a 4-m^2 circular area around each quadrat.

Fixed-plot density measurements

A permanently fixed point was subjectively located in the burned area of each paddock to serve as a reference for yearly observations. Average vegetation conditions were observed in two 15 $\times$ 1-m belt transects beginning 5 m south and north of the fixed point, hereafter referred to as the fixed plot. Densities of *Bromus tectorum*, *Crepis acuminata*, *Purshia tridentata*, and *Artemisia tripartita* were recorded in the fixed plot each summer in late July from 2001 to 2004. Paddock-level treatments were applied.

Data analyses

This study was a randomized complete block design with four replications per treatment. Data were separated into two analyses according to sampling procedure: (1) pre- and post-treatment measurements of cover and density, and (2) fixed-plot measurements of density. Throughout our analyses, we examined change in cover and density variables calculated as the difference between 2001 and 2004 measurements. All statistical comparisons were considered significant if P was <0.05 and means are reported with standard error throughout this document.

In the pre- and post-treatment samples, we excluded any plots that were located in unburned areas, as they were not the focus of this study. A total of 10% of plots were located in unburned areas, averaging 6 ± 1.3 plots per paddock (range 0 to 19). Mean cover and density were calculated for each paddock and the paddock was the sampling unit used throughout our analysis. Data transformations were used to meet assumptions of normality. When observations of specific variables were sparse, means were reported but not analyzed for treatment differences.

Analysis of variance procedures were performed to examine differences in the mean change from 2001 to 2004 by treatment using the treatment by block interaction as an error term to test the main treatment effects. Orthogonal contrasts were conducted to examine the effects of grazing (graze *v.* no graze), season of graze (autumn *v.* spring), and delayed onset of grazing (3 *v.* 2 *v.* 1 year after fire). Statistical analyses were performed in *SAS version 9.1* using PROC GLM (SAS 2004). A weighted least-squares technique was used for pre- and post-treatment analyses of variance using frequency as the weight variable. Frequency was the proportion of quadrats where a species occurred along each transect relative to the total number of quadrats sampled in each transect.

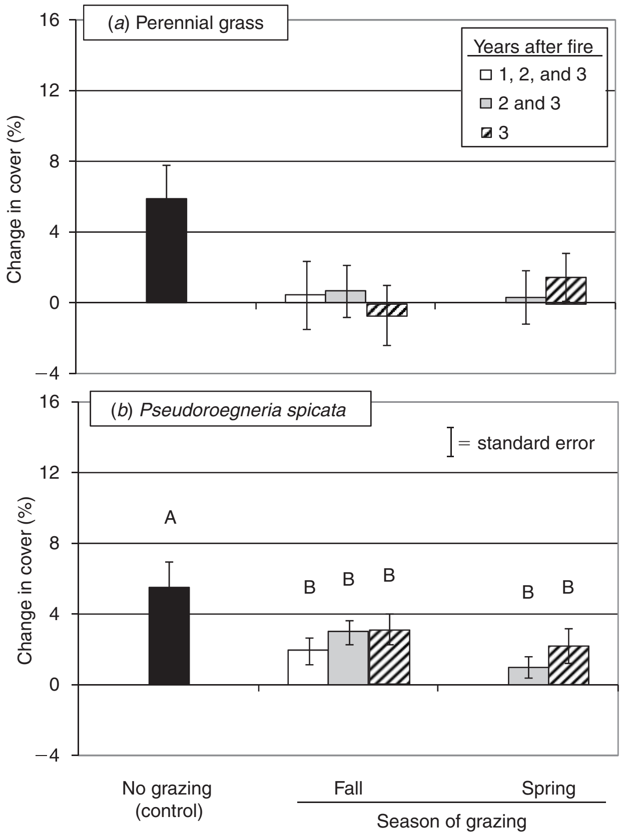

Fig. 2. Change (mean ± s.e.) from 2001 to 2004 in perennial grass (*a*); and *Pseudoroegneria spicata* (*b*) canopy cover for paddocks subjected to sheep grazing in spring or fall (autumn) 1, 2, or 3 years after a wildfire that occurred in 2000. The study was conducted in a sagebrush-steppe area in south-eastern Idaho.

Results

Perennial grass cover

Perennial grass cover averaged 14.7 ± 0.6% in 2001 and 16.1 ± 0.9% in 2004, 1 to 3 years after fire (YAF). Change in mean perennial grass cover was not influenced by any grazing treatment (Fig. 2*a*). Grazed paddocks did not differ from non-grazed control paddocks. Change in perennial grass cover was greater than zero in ungrazed paddocks ($P < 0.01$) but did not differ from zero in grazed treatments.

Examination of canopy cover of individual species revealed that no individual species of grass was affected by the grazing treatments except for *Pseudoroegneria spicata* ($P < 0.05$; Fig. 2*b*). *Pseudoroegneria* was the dominant perennial grass species on the research site, contributing the most to the overall perennial grass category in pre- and post-treatment measurements (27 and 42% respectively). Grazing effectively lessened the magnitude of *P. spicata* cover increase compared with the non-grazed treatment, evidenced by treatment differences revealed in orthogonal contrasts between grazed and ungrazed treatments ($P < 0.001$; Fig. 2*b*). Cover in ungrazed paddocks averaged 3.9 ± 0.8% in 2001 and 9.4 ± 1.2% in 2004. Cover in grazed paddocks averaged 3.9 ± 0.1% in 2001 and 7.3 ± 0.9% in 2004. Change in cover of *P. spicata* was greater than zero in all treatments, regardless of season or delay in onset of grazing, except for paddocks grazed in the spring beginning 2 YAF ($P < 0.05$), where cover change did not differ from zero.

Annual grass cover and density

Cover of annual grasses was not affected by grazing treatments (Fig. 3*a*). Although the values of change from 2001 to 2004 appear to be less when spring-grazed compared with autumn-grazed and control, the magnitude of change was less than 1%. Annual grass cover averaged 1.5 ± 0.1% in 2001 and 2.1 ± 0.2% in 2004. The season of grazing or years that grazing was delayed after fire did not affect the density of *Bromus tectorum* in paddocks before and after grazing was applied (Fig. 3*b*) or in fixed-plot measurements (Table 2). *B. tectorum* density sampled in pre- and post-treatment measurements changed from 1.3 ± 0.1 to 3.7 ± 0.5 plants m^{-2}.

Forb cover, frequency, and density

Based on 2001 and 2004 pre- and post-treatment vegetation measurements, change in perennial cover was unaffected by season of grazing or years of grazing delay after fire at both the life-form and species level of analysis (Fig. 4*a*). Annual forb cover was highly variable among years and paddocks and was also unaffected by season of grazing or years of delay before grazing was resumed after fire. Perennial forb cover averaged 5.1 ± 0.5% in 2001 and 7.1 ± 0.5% in 2004. Annual forb cover averaged 2.8 ± 0.2% in 2001 to 14.4 ± 1.1% in 2004. Perennial forb cover

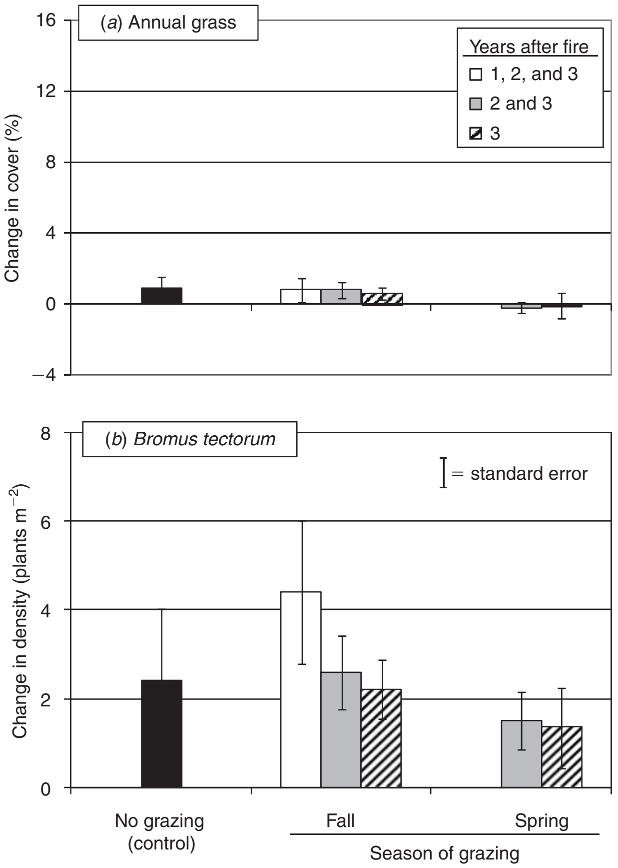

Fig. 3. Change (mean ± s.e.) from 2001 to 2004 in annual grass canopy cover (*a*); and *Bromus tectorum* density (*b*) for paddocks subjected to sheep grazing in spring or fall (autumn) 1, 2, or 3 years after a wildfire that occurred in 2000. The study was conducted in a sagebrush-steppe area in south-eastern Idaho.

change was greater than zero in all treatments ($P < 0.05$) over the study duration, except for paddocks grazed in spring beginning 2 YAF, where change of cover did not differ from zero (Fig. 4*a*). Examination of grazing effects on the cover of individual forb species revealed no treatment effects. However, a closer look at two of the dominant perennial forb species, *Crepis acuminata* and *Balsamorhiza sagittata*, suggested a trend for seasonal grazing effects. Cover change of *C. acuminata* was greater than zero in the control and autumn-grazed treatments but did not differ from zero in spring-grazed treatments ($P < 0.05$). Cover of *C. acuminata* averaged $1.5 \pm 0.1\%$ in 2001 and $2.7 \pm 0.1\%$ in 2004. Cover change of *B. sagittata* was greater than zero where grazing was delayed until autumn 2 YAF ($P < 0.05$) but did not differ from zero in remaining treatments and the control. Cover of *B. sagittata* averaged $0.3 \pm 0.0\%$ in 2001 and $0.6 \pm 0.1\%$ in 2004. Measures of change in frequency, based on 2001 and 2004 pre- and post-treatment vegetation measurements, indicated that *C. acuminata* was greater in paddocks grazed in the autumn 3 YAF compared with control paddocks ($P < 0.05$; Fig. 4*b*). Frequency of *C. acuminata* in the control paddocks averaged $35.3 \pm 3.2\%$ in 2001 and $30.1 \pm 2.5\%$ in 2004. Frequency in the paddocks grazed in the autumn 3 YAF averaged $23.2 \pm 4.5\%$ in 2001 and $29.9 \pm 5.1\%$ in 2004. Change in frequency of *C. acuminata* in paddocks grazed in the spring beginning 2 and 3 YAF was less than zero ($P = 0.01$; Fig. 4*b*) but did not differ from zero in the control and autumn-grazed treatments. Change in densities of *C. acuminata* sampled in fixed-plot measurements was not affected by grazing treatments (Table 2).

Shrub cover and density

Change in shrub cover was not influenced by any of the grazing treatments (Fig. 5*a*). Shrub cover averaged $1.0 \pm 0.1\%$ in 2001 and $3.6 \pm 0.4\%$ in 2004. Densities of *Artemisia tripartita* sampled in pre- and post-treatment measurements were unaffected by grazing treatments (Fig. 5*b*). Density of *A. tripartita* averaged 0.6 ± 0.0 plants m^{-2} in 2001 and 1.1 ± 0.1 plants m^{-2} in 2004. No differences in change in cover or densities were detected for *A. tripartita* or *Purshia tridentata* in pre- and post-treatments measurements or fixed-plot measurements (Table 2).

Discussion

In this study, moderate sheep grazing had subtle impacts on vegetation recovery after fire. We observed a general increase in cover of *Pseudoroegneria spicata*, the dominant perennial grass occurring in this study, 4 years following wildfire. The increase in cover of *P. spicata* was somewhat suppressed by moderate grazing, though the species increased in cover despite drought conditions the year after the burn. Post-treatment cover measurements showed a potential trend for increased *P. spicata* cover in non-grazed and autumn treatments compared with spring-grazed treatments. However, seasonal differences in grazing treatments were not significant in our model. The natural recovery period for *P. spicata* after fire is generally two to three growing seasons (Uresk *et al.* 1980; West and Hassan 1985), though recovery may be slowed by seasonal grazing. Seasonal sheep-grazing effects are well documented in this region and numerous studies indicate that spring grazing may lower perennial grass cover compared with autumn grazing (Mueggler 1950; Laycock 1967; Bork *et al.* 1998). Jirik and Bunting (1994) examined the extent of seasonal grazing impacts on *P. spicata* after fire and found an effect from early season grazing but did not detect differences between late-season grazing and non-grazed controls.

In examining the long-term effects of spring grazing in this region, repeated spring grazing will decrease the forb community over time (Mueggler 1950; Laycock 1967; Bork *et al.* 1998). In the spring, sheep will preferentially graze early-growing forbs, reducing overall forb production 73%, and forbs such as *Balsamorhiza sagittata*, *Comandra umbellata* (bastard's toadflax), *Crepis acuminata*, and *Eriogonum heracleoides* (parsnipflower buckwheat) were reduced more than 85% (Laycock 1967). However, certain forb species often increase following fire (Seefeldt *et al.* 2007). Although we anticipated a detectable reduction in cover of dominant perennial forbs following spring-grazing treatments, we were unable to detect seasonal differences in grazing treatments. Our hypothesis was supported to some extent by a trend for increased perennial forb cover in the control and autumn-grazed treatments over the study duration compared with spring-grazed treatments. The cover of two important forbs *C. acuminata* and *B. sagittata* also followed this same trend, weakly revealed by *t*-tests of change in pre- and post-treatment cover. This trend agrees with other studies documenting the

Table 2. Summary of fixed-plot density (plants 10 m^{-2}) measurements recorded in belt transects at research site in south-eastern Idaho
Densities were recorded from 2001 to 2004 in paddocks subjected to sheep grazing in spring or autumn 1, 2, or 3 years after a wildfire (YAF) that occurred in 2000

Species	Year	Treatment					
		Control (ungrazed)	Grazed autumn 1, 2, 3 YAF	Grazed spring 2, 3 YAF	Grazed autumn 2, 3 YAF	Grazed spring 3 YAF	Grazed autumn 3 YAF
Bromus tectorum	2001	7.7 ± 3.4	18.3 ± 9.8	13.0 ± 5.8	9.8 ± 5.3	54.3 ± 17.3	32.9 ± 14.7
	2002	10.7 ± 8.3	12.4 ± 5.9	49.1 ± 14.6	8.3 ± 4.0	102.7 ± 60.2	36.0 ± 16.8
	2003	10.5 ± 3.4	48.9 ± 38.8	35.6 ± 6.9	25.7 ± 8.8	94.4 ± 45.3	72.7 ± 26.4
	2004	10.4 ± 3.0	49.5 ± 38.3	35.0 ± 6.9	11.8 ± 2.8	59.7 ± 18.4	47.1 ± 20.6
Crepis acuminata	2001	24.5 ± 5.1	26.8 ± 3.7	41.9 ± 5.8	31.0 ± 7.6	27.6 ± 8.9	34.3 ± 16.8
	2002	55.1 ± 7.2	53.2 ± 13.0	56.4 ± 13.6	52.0 ± 6.1	49.0 ± 8.7	49.3 ± 19.0
	2003	67.3 ± 6.4	62.6 ± 12.1	41.6 ± 13.2	72.3 ± 15.7	18.5 ± 2.0	50.4 ± 21.2
	2004	60.3 ± 10.2	58.4 ± 12.7	57.1 ± 11.4	58.1 ± 15.4	43.3 ± 15.9	44.6 ± 20.4
Artemisia tripartita	2001	1.0 ± 0.8	0.9 ± 0.4	3.4 ± 1.8	3.4 ± 2.8	3.1 ± 1.8	1.1 ± 0.5
	2002	2.0 ± 1.2	1.2 ± 1.1	5.2 ± 1.9	5.4 ± 3.5	5.2 ± 3.0	2.2 ± 1.3
	2003	2.2 ± 1.3	2.3 ± 1.3	4.9 ± 1.6	5.5 ± 3.0	5.0 ± 3.1	2.8 ± 1.2
	2004	0.9 ± 0.4	2.7 ± 1.4	4.3 ± 1.9	3.8 ± 1.8	4.4 ± 3.2	2.3 ± 1.4
Purshia tridentata	2001	0.4 ± 0.3	0.3 ± 0.1	0.1 ± 0.1	0.7 ± 0.2	0.0 ± 0.0	0.8 ± 0.5
	2002	0.3 ± 0.2	0.5 ± 0.4	0.3 ± 0.3	0.9 ± 0.4	0.0 ± 0.0	0.7 ± 0.3
	2003	0.6 ± 0.3	0.3 ± 0.2	0.2 ± 0.2	0.8 ± 0.3	0.0 ± 0.0	0.5 ± 0.4
	2004	0.3 ± 0.2	0.2 ± 0.1	0.2 ± 0.2	0.6 ± 0.3	0.0 ± 0.0	0.4 ± 0.3

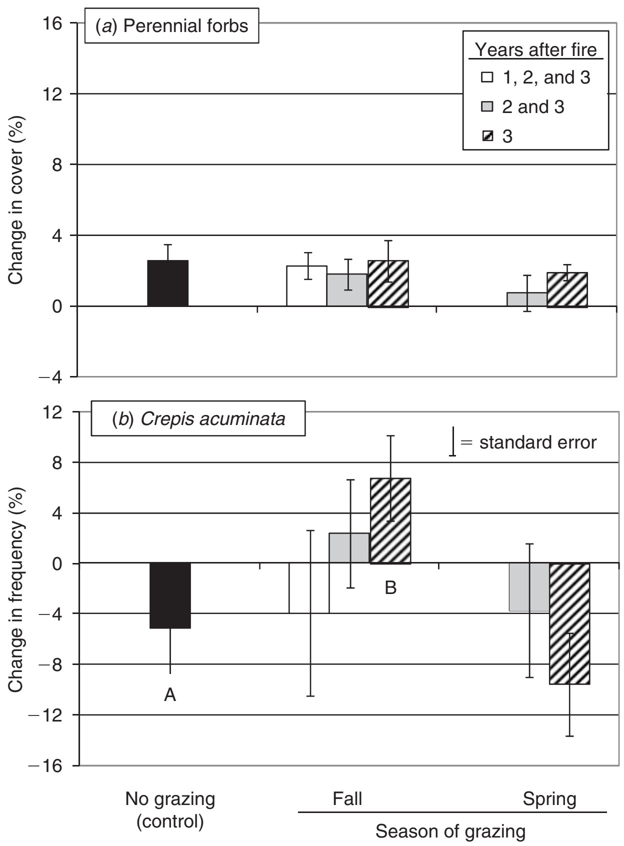

Fig. 4. Change (mean ± s.e.) from 2001 to 2004 in perennial forb canopy cover (*a*); and *Crepis acuminata* frequency (*b*) for paddocks subjected to sheep grazing in spring or fall (autumn) 1, 2, or 3 years after a wildfire that occurred in 2000. The study was conducted in a sagebrush-steppe area in south-eastern Idaho.

decline of forbs as a consequence of sheep grazing in the spring (Bork *et al*. 1998; Seefeldt and McCoy 2003).

Grazing treatments did not influence *Artemisia tripartita* populations in the present study. Long-lived shrub species like *A. tripartita* are slow to recover after burning, making it difficult to detect grazing effects on sagebrush in the aftermath of fire (K. DiCristiana, M. Germino, S. S. Seefeldt, unpubl. data). Success of *Artemisia tridentata* ssp. *vaseyana* (mountain big sagebrush) establishment in study sites 6 to 10 km to the east of the present study was positively impacted, with decreased competition from surrounding plants (K. DiCristiana, M. Germino, S. S. Seefeldt, unpubl. data). Early autumn sheep grazing may provide the release needed to enhance *A. tripartita* establishment. A unique characteristic of *A. tripartita* is that it may resprout after fire (Hironaka *et al*. 1983). Some of this resprouting was observed but it was rare and quite patchy. *Purshia tridentata*, a valuable wild ungulate forage resource, was not affected by grazing treatments in our study. In eastern Idaho, *P. tridentata* commonly resprouts from the root crown after fire (Blaisdell and Mueggler 1956), and it was regularly observed sprouting in the present study.

We anticipated that *Bromus tectorum* would rapidly increase on this site after the wildfire – a common scenario in western rangelands (Whisenant 1990; Knapp 1996; Mosley 1996; Seefeldt and McCoy 2003). In our study, *B. tectorum* contributed very little to the vegetation composition (0.1 to 3.4%), increased only slightly from 1 to 4 years after fire (0.8 to 1.2%), and the grazing treatments had no detectable effect on annual grass cover and density. Grazing treatment effects might have been observed if climatic conditions had resulted in typical autumn germination and growth of *B. tectorum*, possibly resulting in a vigorous early spring population. Population dynamics of winter annual grasses, such as *B. tectorum*, are largely driven by seasonal climatic conditions (Mack and Pyke 1983). The lack of annual grass

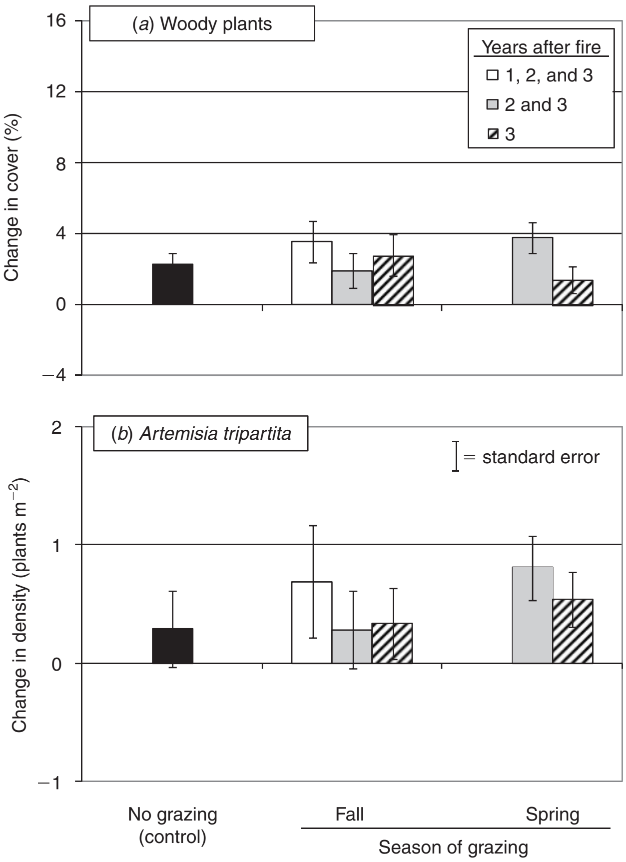

Fig. 5. Change (mean ± s.e.) from 2001 to 2004 in woody plant canopy cover (*a*); and *Artemisia tripartita* density (*b*) for paddocks subjected to sheep grazing in spring or fall (autumn) 1, 2, or 3 years after a wildfire that occurred in 2000. The study was conducted in a sagebrush-steppe area in south-eastern Idaho.

abundance on this site the year after fire probably resulted from the lack of autumn precipitation. The few *B. tectorum* seedlings that had emerged to the one- to two-leaf stage before snow accumulation did not survive the winter. This same climactic scenario of little autumn precipitation was repeated in the following 2 years (Fig. 1). Spring-germinated *B. tectorum* plants often exhibit reduced height and yield (Stewart and Hull 1949) and were likely further limited by low precipitation in the spring following the burn. *B. tectorum* seed caryopses may not have been prevalent before the fire and additional mortality may have occurred from heat damage associated with the burn (Young *et al*. 1976). However, limited abundance of annual grasses in healthy sagebrush stands before fire does not preclude post-fire establishment of these grasses (West and Hassan 1985).

Current federal policy requiring a period of rest from grazing following wildfire is partially supported by our study in regard to effects on the dominant herbaceous plant species. One to two weeks of moderate spring sheep grazing, in the absence of a dense annual grass infestation, had little affect on the cover of native vegetation following fire. However, a trend in this study for increased *Pseudoroegneria spicata* (the species of greatest management concern in our study area), *Crepis acuminata*, *Balsamorhiza sagittata*, and *Artemisia tripartita* cover over time under moderate, 1 to 2-week-duration autumn sheep grazing that removes 40% of the plant biomass is evidence that autumn-grazed treatments do not necessarily have a negative impact. These trends are particularly important because our study took place during drought conditions. If autumn grazing can be managed at moderate levels, effects on native perennial vegetation may be undetectable.

Land managers may need to evaluate burned vegetation on a site-specific basis in contrast to mandating a set deferment period (K. Sanders, pers. comm.). Rest periods may need to reflect pre-fire site conditions (i.e. stable communities *v.* at-risk late seral stands or stands with pre-fire weed infestations; Seefeldt *et al*. 2007). Mandatory rest periods may impose undue financial hardship to local livestock producers and prove increasingly challenging to land managers. Careful attention should be placed on planning objectives for post-fire recovery (i.e. sensitive species, forage resource, weed invasion). Managers should develop grazing management strategies that limit damage to recovering vegetation while minimizing the threat of weed invasion and increased fuel loads increasing the potential for reoccurring fire. Management decisions on when to start grazing livestock after fire should consider pre-fire ecological conditions, post-fire climatic conditions, and current knowledge of impacts of grazing on plant recovery.

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